# DEVELOPMENT AND USE OF THE SOIL MANAGEMENT ASSESSMENT FRAMEWORK

B.J. Wienhold and S.S. Andrews
USDA-ARS, Lincoln, NE and USDA-NRCS, Ames, IA
bwienhold1@unl.edu (402) 472 1484

## ABSTRACT

Soils perform a number of critical functions essential to productivity and environmental quality. Management practices affect these soil functions. However, spatial and temporal variation and the slow rate of change in many soil properties make it difficult to assess the effects of management on soil functions. Tools are needed to assist managers in making assessments of the effect their management practices are having on the soil resource. The Soil Management Assessment Framework (SMAF) uses scoring curves to interpret soil indicator data. The values generated using the scoring curves can be used individually or can be combined to make comparisons among management practices or to assess a management practice over time. A case study is presented comparing a number of management systems in the Northern Great Plains. Conclusions reached using the SMAF confirmed those reached based on professional judgment in earlier publications. While scoring curves for additional soil indicators are needed, the SMAF provides an objective way of assessing management affects on soils.

## INTRODUCTION

Management effects on the soil resource can be difficult to assess. Common approaches to soil management assessment involve measurement of indicator soil properties and comparison of these properties over time or comparison of these properties among alternate management practices. Such assessments are complicated by spatial variability within a field, temporal variability during a growing season, slow rates of change, and limits in our ability to detect small but meaningful changes in indicators. Assessment tools are needed to assist managers in determining management impacts on the soil resource. Such tools need to provide assistance in selecting the best indicators for assessing selected management goals, interpretation of the effect indicator values have on soil functions, and provide a way to assess changes over time and among alternate management practices (Andrews and Carroll, 2001). The Soil Management Assessment Framework (SMAF) is a tool having potential for assisting in these three steps (Andrews et al., 2002). The objective of this paper is to describe the current version of SMAF, the scientific basis for its indicator scoring curves, and to demonstrate use of the SMAF with case studies from the Northern Great Plains.

The SMAF is a three-step process consisting of indicator selection, interpretation, and integration. Indicator selection involves identifying the management goal and the soil indicators that affect soil functions influencing that goal. There are three management goals and six soil functions in the current version of SMAF. Indicator selection can be accomplished using selection rules included in the SMAF or the user can select indicators known to be important in meeting the management goal that have scoring curves developed for them. Indicators should be selected by considering management practices, climate, and inherent soil properties.

The second step, interpretation, involves converting soil indicator values to an index value, using indicator scoring curves. The current version of the SMAF has scoring curves for 11 indicators (Table 1). A number of additional indicators have been identified as having potential for inclusion in the SMAF (Table 1). Efforts are underway to develop additional scoring curves to be included in future versions of SMAF and to modify or validate existing scoring curves for additional climates, soils, and crops.

Table 1. Soil indicators having scoring curves in the current version of the Soil Management Assessment Framework and a partial list of indicators having potential for development of scoring curves.

| Current Indicators | Potential Indicators |
|---|---|
| Organic C Concentration | Water Filled Pore Space |
| Macroaggregate Stability | Nitrate-N Concentration |
| Microbial Biomass | Topsoil Depth |
| Potentially Mineralizable N | Infiltration Rate |
| pH | Enzyme Activity (e.g. b-glucosidase) |
| Extractable P | Exchangeable K |
| $qCO_2$ | Total Soil N |
| Bulk Density | Earthworms |
| Electrical Conductivity | Respiration |
| Sodium Adsorption Ratio | C:N Ratio |
| Available Water Capacity | and others |

Scoring curves transform an observed indicator measure to an index value based on the effect that indicator has on a soil function. When using raw indicator measurements it is often difficult to determine how great a difference is needed before a functional difference is present. Conversion to index values assists in interpreting indicator data by providing a unitless value that can be compared over time or between alternative management practices (Karlen and Stott, 1994).

Scoring curves most often take one-of-three forms: more is better, less in better, or local maximum (Fig 1). The scoring curve for organic C concentration (OC) is an example of a more is better curve based on the role of organic matter in soil fertility and soil stability. Other indicators that use a more is better curve are aggregate stability, microbial biomass C, potentially mineralizable N (PMN), and available water capacity. The scoring curve for bulk density (BD) is an example of a less is better curve based on the relationship between bulk density and porosity and root growth. Other indicators that use a less is better scoring curve are sodium adsorption ratio and electrical conductivity (EC). The scoring curve for pH is an example of a local optimum based on the relationship between pH and nutrient availability. Nutrients essential for plants are optimally available at a given pH and decline in availability at higher or lower pH's. The other indicator that uses a local optimum scoring curve is extractable P.

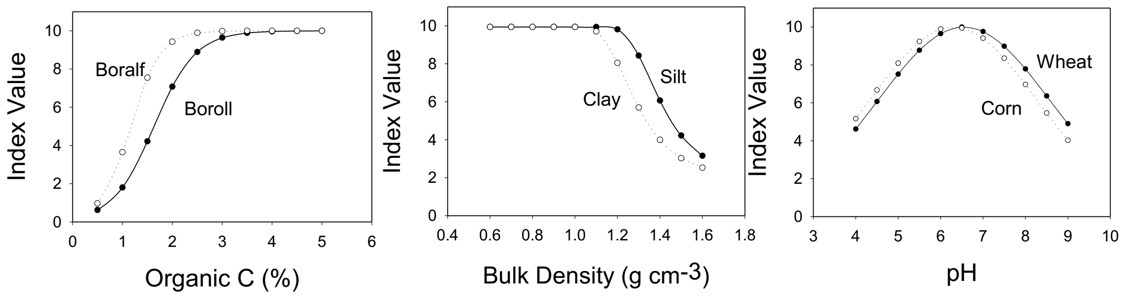


Fig. 1 Examples of scoring curves for organic carbon, bulk density, and pH (after Andrews et al., 2004).

The most recent improvement to the SMAF is the inclusion of scoring curves that are adjusted, causing the curve to shift, to account for differences among soils due to inherent soil properties and climate or for differences in crop sensitivity to the indicator (Fig. 1). The adjustments are accomplished by using logic statements and alternative algorithm parameters dependent on site-specific factors (Andrews et al., 2004). This allows the SMAF to be transferable among many regions, soils, and management systems.

The third step, integration, involves combining the individual index values to generate an overall index value that can be compared among management practices, or to assess a management practice over time. This is the least important step and can be skipped if the manager prefers to make the assessment by interpreting the individual indicators. If the integration step is used there are several ways that individual indicators can be combined. Andrews et al. (2002) compared additive, weighted, and a decision support system (that used the additive value function method to solve hierarchical multi-attribute problems) as ways to combine index values and found similar results for the three methods. In the present case study, indicator index values were summed to form an overall index value that could be compared among the treatments.

## MATERIALS AND METHODS

Results from two long-term studies in the Northern Great Plains were used to demonstrate the utility of the SMAF as a way of comparing management practices. The first study was a cropping system study initiated in 1984 to compare a 3-yr annual cropping system to crop-fallow under three levels of tillage (no-tillage, minimum tillage, and conventional tillage), and three levels of N fertilization. In 1998, physical, chemical, and biological soil attributes were compared among these treatments (Wienhold and Halvorson, 1998). In 1999, differences in PMN among the treatments were compared (Wienhold and Halvorson, 1999). The second study was a grazing trial initiated in 1916 to assess the effects of grazing pressure on the mixed grass prairie vegetation. In 1932 a fertilized tame grass pasture treatment was added to the grazing trial. In 2001, physical, chemical, and biological soil attributes under no grazing, moderate long-term grazing, heavy long-term grazing, and in the grazed tame pastured were compared (Wienhold, et al., 2001). Soils at both the cropping system site and the grazing site were Temvik-Wilton silt loam (fine-silty, mixed Typic, and Pachic Haploborolls).

Bulk density was selected as a physical attribute; OC concentration, EC and pH were selected as chemical attributes; and PMN was selected as a biological attribute (Doran and Jones, 1996). These five indicators were selected because the current version of the SMAF has scoring curves for these indicators and all five were measured in treatments for both field studies. Values for these five attributes were entered into a spreadsheet, index values were calculated using the SMAF scoring curves, and the individual index values were summed to provide an overall index value. Indices were computed for each of six original treatments (no grazing, moderate grazing, heavy grazing, grazed fertilized tame, conventionally tilled crop-fallow, and no-tillage annually cropped). An ANOVA was used to detect differences among the treatments (SAS Institute, Cary, NC[1]).

## RESULTS AND DISCUSSION

In the cropping system study, Wienhold and Halvorson (1998, 1999) concluded that more intensive cropping and conservation tillage increased N-mineralization rates and improved soil quality when compared to crop-fallow. In the grazing trial study, Wienhold et al., (2001) concluded that moderate grazing and grazing fertilized tame pasture were viable management options that appear to sustain the soil resource. Conclusions reached in both of these studies were somewhat subjective in that while they were based on differences in soil attributes, professional judgment was used to describe the implications of those differences on the soil resource.

Soil attribute data from the two studies was reevaluated using the SMAF. Index values for the individual soil attributes revealed that OC was lower in the cropped systems than in the grazed systems; PMN was lower in the ungrazed and heavily grazed treatments; and EC was lower in the cropped treatments than in the grazed treatments (Fig. 2). When the index values were summed the management practices were ranked in the following order: grazed fertilized tame pasture > moderately grazed > ungrazed > heavily grazed > annual cropping with no-tillage > conventionally tilled crop-fallow (Fig. 2). These results confirm those in the original reports (Wienhold and Halvorson, 1998, 1999; Wienhold et al., 2001).

The SMAF index is much less subjective in that the same scoring curves were used to interpret the measured soil indicators in both the grazing and cropping systems studies. While work is needed to develop scoring curves for additional soil indicators, the SMAF index appears to have potential for assessing management practice effects on the soil resource. This framework could serve as an expert system to facilitate the assessment of soil function for land managers.

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[1] Mention of trade names is for the benefit of the reader and does not constitute endorsement by the U.S. Department of Agriculture over other products not mentioned.

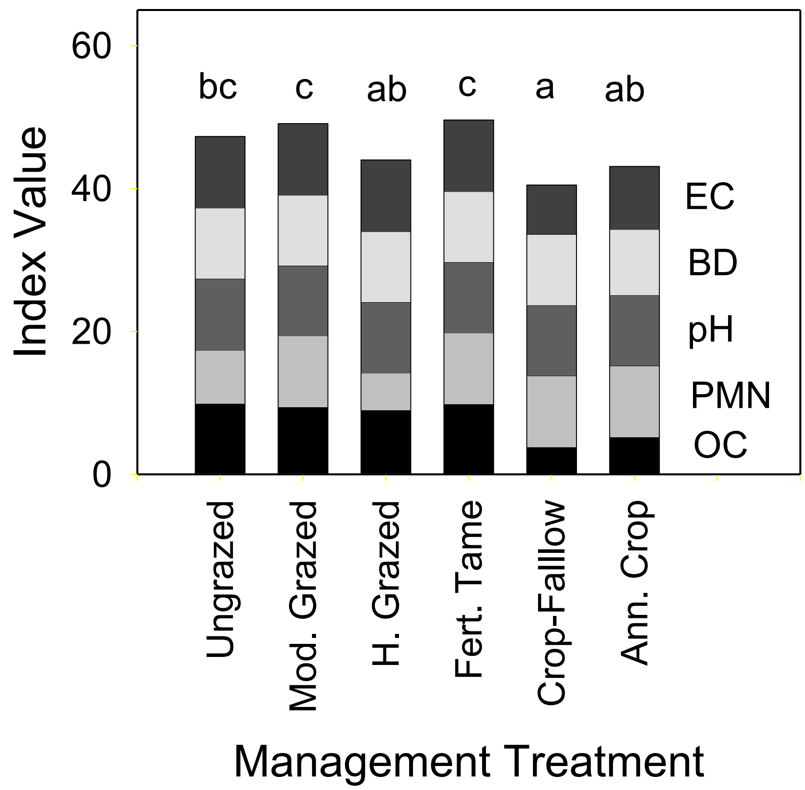


Fig. 2. Comparison of management treatments in the Northern Great Plains using the Soil Management Assessment Framework. Soil indicators used were organic C (OC), potentially mineralizable N (PMN), pH, bulk density (BD), and electrical conductivity (EC). Bars having different letters above them are different at $p < 0.05$ (after Wienhold et al., 2004).

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